Efficient Analysis of Microwave Devices Based on Polygonal Modeling and WIPL-D Numerical Engine

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Abstract: Surface formulation of method of moments gives the best results in electromagnetic analysis when geometrical modeling is performed with quadrilateral patches. Quadrilateral modeling, however, can be very difficult. Many structures, e.g. different microwave devices, can be easily modeled using polygonal surfaces. This paper presents general method for conversion of polygonal model into quadrilateral model. Proposed method is illustrated on real microwave filter.

Keywords: Method of Moments, Polygonal Modeling, Microwave Devices.

1. Introduction

Analysis of electromagnetic problems in frequency domain is often performed using method of moments (MoM) applied on surface integral equations. Appropriate model for this purpose includes patches which represent real object surfaces. MoM numerical engine typically supports triangle or quadrilateral patches. It is shown [1] that use of quadrilateral patches results in more efficient analysis, while triangle patches are more suitable for modeling (e.g. for curved surfaces). However, in both cases modeling process can be very tedious. On the other hand, many structures, especially microwave devices, can be easily modeled using polygons. This paper introduces original concept of polygonal modeling together with automatic procedure for conversion of such polygonal model into operative quadrilateral model.

2. Overlapped polygonal model

Overlapped polygonal model consists of flat polygons which represent model surfaces. It is allowed coplanar polygons to intersect. Polygons from different plane must not intersect and can have contact only along polygon edges. Typical modeling process is illustrated in Fig. 1a-1c, after the first, the second and the third polygon is created in the same plane. Fig. 1c visually indicates model assembly – areas that belongs to more than one polygon inherit properties of last created polygon.

3. Connected quadrilateral model

WIPL-D [2] is commercial application for electromagnetic modeling. Its numerical engine "recognizes" curved quadrilateral patches (bilinear surfaces) which special case are flat quadrilaterals. Patches must cover model surfaces without overlapping and along common edge must have the same nodes. Furthermore, flat quadrilaterals should be convex. Any deviation from these rules results in decreased accuracy. We will call such model, used within WIPL-D, connected quadrilateral model.

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4. Conversion of overlapped polygonal model into connected quadrilateral model

Overlapped polygonal model is introduced in order to ease modeling. User creates polygonal model which is automatically converted into connected quadrilateral model. This automated procedure involves following actions:

- Intersect all coplanar polygons,
- Create complex polygons for all model planes,
- Establish connections between polygons from different planes,
- Transform all odd polygons into even,
- Perform independent quadrilateral meshing for each complex polygon.

We will briefly introduce every procedure step. Final step is in more details presented in [3].

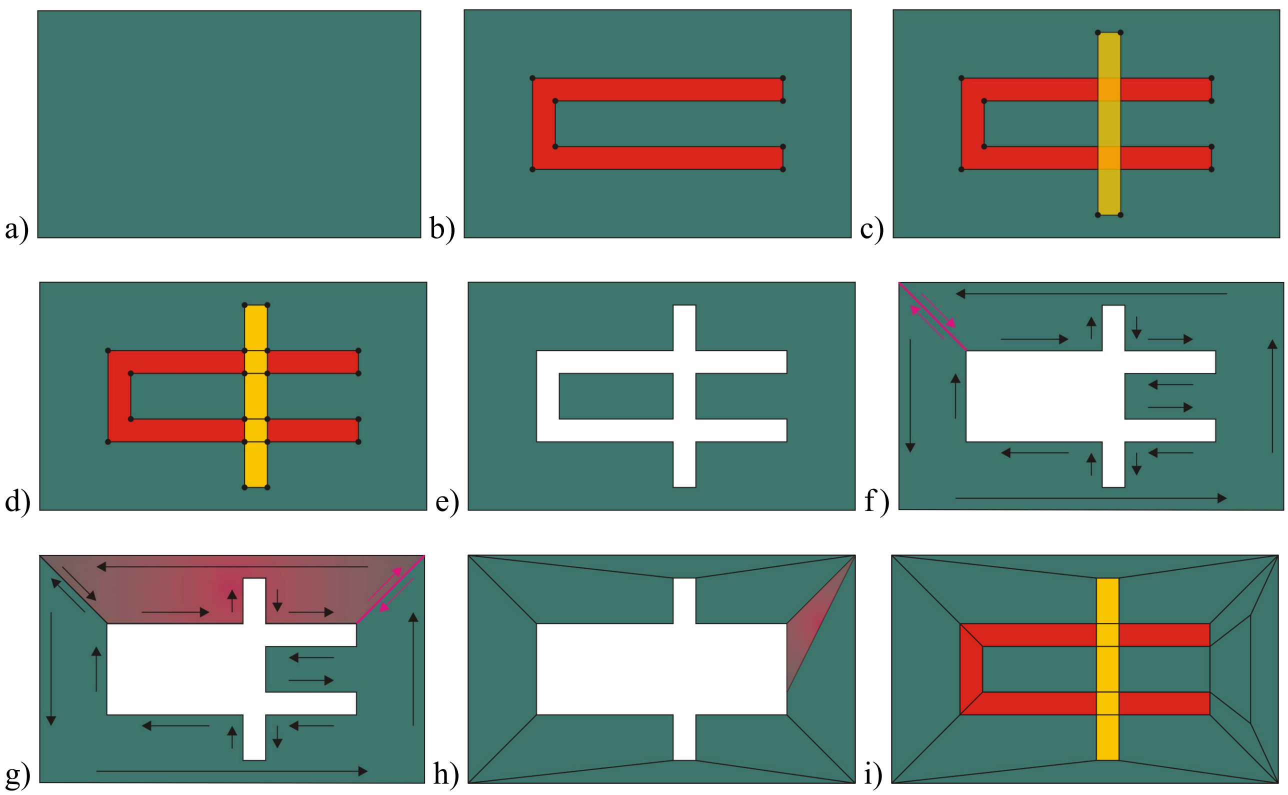


Figure 1. (a)-(c) Creating overlapped polygonal model, (d) Polygons intersection, (e) Forming complex polygons, (f)-(h) Initial meshing, (i) Mesh after refinement.

In order to establish connections between coplanar polygons we must intersect them. Result of two polygons intersection is a set of new polygons. If new polygon belongs to both initial polygons it inherits properties of last created polygon. Fig. 1d shows situations after red and yellow polygon intersect. All common polygons inherited yellow polygon properties.

Meshing is performed on complex polygons. Such polygons consists of one external and arbitrary number of internal contours. Meshing procedure works correctly only if internal contours are mutually isolated. Hence, all internal contours that have common nodes must be joined. Result of two contours join is one external and arbitrary number of internal contours. Newly generated external contour is new internal contour of complex polygon, while newly generated internal contours represents new external contours of complex polygons. External contour of complex green polygon is shown in Fig. 1a, and all red and yellow polygons in Fig. 1c are its internal contours. Fig. 1e shows situation after all internal contours are joined. Newly generated external contour is new internal contour for green complex polygon (as in Fig. 1f). Newly generated internal contour (little green rectangle in Fig. 1e) represents external contour of new complex polygon.

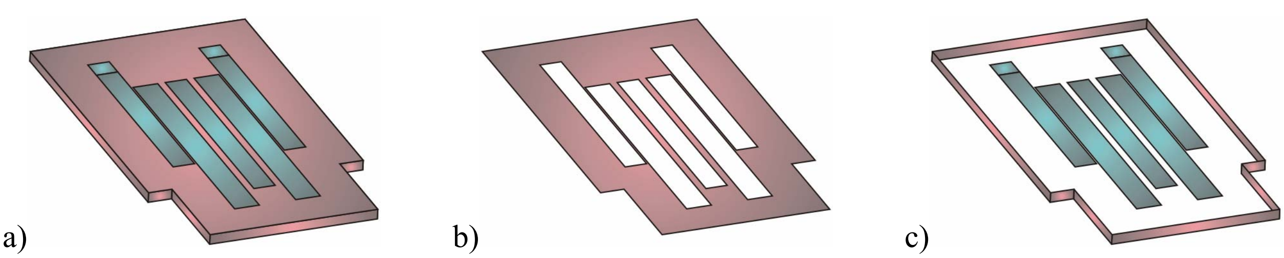
Previous steps provide connected polygons within planes. Still, connection between different planes must be established. This can be done by establishing connections between each pair of polygons from different planes. First a common edge between polygons is found. Then, if some node along this edge belongs to only one of two polygons, it is included into the other polygon.

Complex polygon can be “covered” with quadrilateral mesh only if its number of segments is even. Odd polygon can be transformed into even by inserting one node at its edge. On the other side, complex polygons can not be meshed independently if new nodes are inserted on polygon edges during meshing. Therefore all odd polygons are transformed to even before meshing. General procedure employed here includes search for optimal path between odd polygons and inserting nodes along it. Path is an array of polygons where neighboring polygons in array have common edge. For every pair of polygons in the array node is inserted on their common edge. The first and the last polygon in the path (these two were odd) get one new node and become even, while the others get two new nodes and remain even. Procedure is repeated until all polygons become even.

Meshing of individual polygons is a finale stage of the conversion. First step is elimination of internal contours in iterative procedure. In each iteration we create one new segment which connects internal and external contour, or two internal contours. This is illustrated in Fig. 1f where new segment attaches internal contour to external contour. When all internal contours are attached to the external, initial meshing is performed as iterative procedure. In every iteration we create one new segment which split original contour in two new contours, as it is illustrated in Fig. 1g. This procedure is finished when all generated contours are quadrilaterals of arbitrary shape. Finally, such initial mesh is refined. In refinement procedure we merge quadrilaterals of bad shape with neighboring quadrilaterals into hexagons. Then we mesh such hexagons into convex quadrilaterals. Concave quadrilateral mark in Fig. 1h is merged with neighboring quadrilateral and meshed into convex hexagons. Final mesh (connected quadrilateral model) is shown in Fig. 1i.

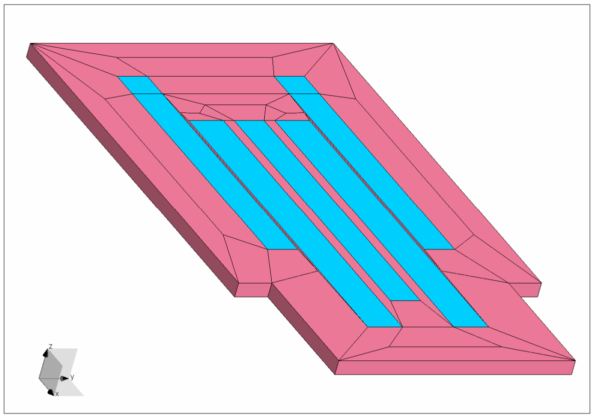
5. Numerical example

Band-pass microwave filter is modeled with polygons as in Fig. 2a. Only one polygon has internal contours (Fig. 2b), while others are rectangles and do not need meshing (Fig. 2c). Automated meshing is shown in Fig. 3a, and S_{12} parameter for this model in Fig. 3b. We observe good convergence of results with increasing unknown numbers. Manual model [4] is shown in Fig. 4a, and S_{12} parameter for this model in Fig. 4b. Convergence of results is similar as for automatic model.



a) b) c)

Figure 2. Band-pass microwave filter.

a) 

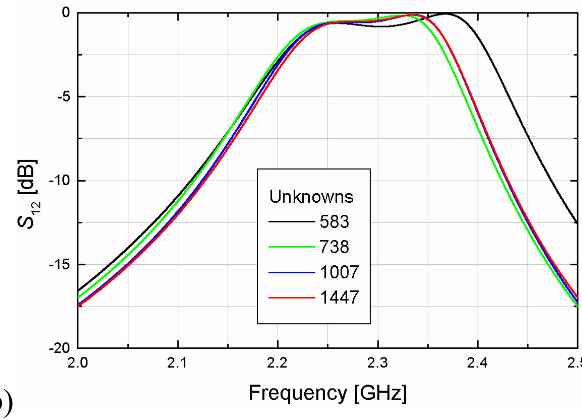
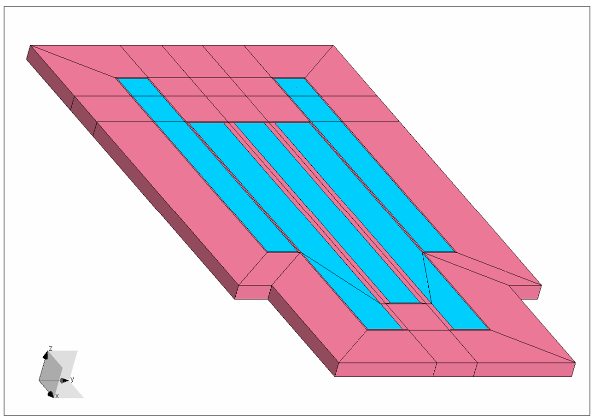
b) 

Figure 3. Automatically generated model, (a) Meshing, (b) S_{12} parameter.

a) 

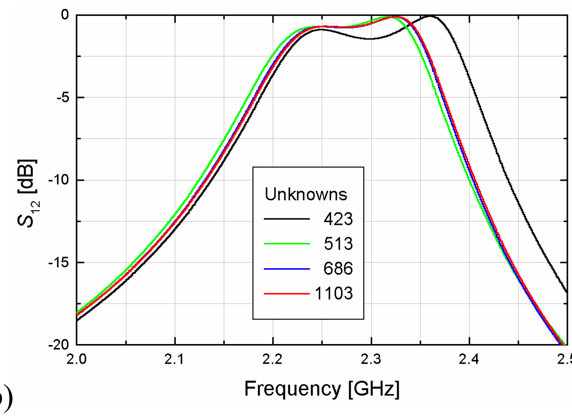
b) 

Figure 4. Manually generated model, (a) Meshing, (b) S_{12} parameter.

6. Conclusion

Automated procedure for conversion of overlapped polygonal model into connected quadrilateral model is presented. Introduced concept offers ease of modeling without significant decrease of accuracy of analysis. Method is particularly suitable in microwave devices modeling. Real-life microwave filter is modeled manually and automatically, using proposed method. Good convergence of S_{12} parameter results exists in both cases, indicating practical benefit of polygonal modeling.

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